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RESEARCH ARTICLE

The Impact of Pediatrician Supply on Child Health Outcomes: Longitudinal Evidence from Japan

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Objective. To investigate the effect of pediatrician supply on under-5 mortality over the period 2000–2010.

Data Sources. Multiple publicly available data sources were used.

Study Design. Japan's 366 "Secondary Tier of Medical Care Units" (STMCU) were used as study units. To evaluate the association between under-5 mortality and pediatrician supply, we explored time and area fixed-effects Poisson regression model. The following factors were introduced into the models as time-varying controls: (1) number of physicians other than pediatricians per total population except for under-5-year-old population, and (2) income per total population by year and STMCU. Extensive sensitivity analyses were conducted to assess robustness of results.

Principal Findings. Pediatrician density was inversely associated with under-5 mortality. We estimated that a unit increase in pediatrician density was associated with a 7 percent (95 percent CI: 2–12 percent) reduction in the child mortality rate after adjustment for all other variables. The results were consistent and robust across all specifications tested.

Conclusions. The results suggest that increasing human health resources can have positive effects on child health, even in settings where child mortality of less than 5 per 1,000 has been achieved.

Key Words. Human resources for health, pediatrician supply, under-5 mortality, Japan

Physicians are a limited health care resource, and determining the optimal distribution of physicians presents a major challenge to health systems in both industrialized and developing countries (Kobayashi and Takaki 1992; McEldowney and Berry 1995; Rosenthal, Zaslavsky, and Newhouse 2005; Gorman, Poole, and Scott 2007; Matsumoto et al. 2010). In Japan, universal health care was introduced in 1961, and it greatly increased the demand for medical services as well as the need for medical professionals. In an effort to increase enrollment in medical schools, the Japanese government mandated the establishment of at least one medical school per prefecture in the 1970s. By the mid-1980s, the number of medical graduates, or newly certified physicians exiting medical school, had doubled from about 4,000 to 8,000 per year. In 1984, the Ministry of Health and Welfare announced that the goal of 1.5 physicians per 1,000 population had been achieved. As a result, Japan's medical school admissions were reduced to prevent future oversupplies of physicians beginning in 1985, diverging in its trajectory from most other industrialized nations, who continued to increase the number of physicians to meet increasing demands generated by medical technology advancements and aging societies.

By 1993, the number of students entering Japan's medical schools had fallen to 7,725, a 7.7 percent reduction from 1984. By 2007, the number of physicians per 1,000 population was 2.1, placing Japan 26th among the 30 OECD countries (Organisation for Economic Cooperation and Development [OECD] 2013). In response to the perceived shortages, the Ministry of Education, Culture, Sports, Science, and Technology decided to increase medical school admissions for the first time in 28 years, resulting in 7,793 new admissions in 2008. In 2011, 8,923 new students were admitted, a 17 percent increase from the low point at the beginning of the century.

Policy interventions to increase physician supply or improve the physician distribution are based on the assumption that the number of medical practitioners is causally related to improved population health (Miller and Stokes 1978; Kim and Moody 1992). However, previous studies have not found a consistent linkage between physician supply and child population health improvement (Miller and Stokes 1978; Grossman and Jacobowitz 1981; Flegg 1982; Pampel and Pillai 1986; Kim and Moody 1992; Hertz, Hebert, and Landon 1994; Cochrane, St. Leger, and Moore 1997; Vogel and Ackermann 1998; Robinson and Wharrad 2000; Anand and Barnighausen 2004; Or, Wang, and Jamison 2005; Aakvik and Holmas 2006; Farahani, Subramanian, and Canning 2009; Muldoon et al. 2011). In addition, most previous investigations have been limited by their focus on the total supply of

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physicians, with two notable exceptions. Cochrane, St. Leger, and Moore (1997) used the disaggregated number of pediatricians and obstetricians in addition to the total number of physicians from 18 developed countries and showed pediatrician density had an adverse effect on infant and perinatal mortality rates. Goodman et al. (2002) focused entirely on the United States, dividing regional availability of neonatology resources into quintiles; the second lowest supplied quintile had the lowest neonatal mortality rates, while the highest supplied quintile, with over four times more neonatologists per capita, shared the highest mortality rates with the lowest supplied quintile.

Japan offers an interesting setting for studying the interactions between provider density and health outcomes. In 2010, the number of physicians per 1,000 population in Japan was 2.23, which ranked the nation 11th lowest in physician density among the 42 countries belonging to the Organisation for Economic Cooperation and Development (OECD 2013). Given that, Japan ranked among the top five nations with respect to under-5 mortality (United Nations Children's Funds [UNICEF] 2013). This could be interpreted as evidence for physician access not being particularly important for child health consistent with some papers from developed countries (Miller and Stokes 1978; Pampel and Pillai 1986; Cochrane, St. Leger, and Moore 1997). This generally mixed evidence conflicts with studies from developing countries or studies including both developing and developed countries, which in general have found either a beneficial association (Flegg 1982; Robinson and Wharrad 2000; Anand and Barnighausen 2004; Farahani, Subramanian, and Canning 2009; Muldoon et al. 2011) or no association at all (Kim and Moody 1992; Hertz, Hebert, and Landon 1994).

The objective of the current study was to investigate the effect of pediatrician supply on under-5 mortality in Japan, that is, in a setting with a relatively low physician-to-population ratio and low rates of infant mortality, by exploring medical district-level variations in pediatrician coverage from 2000 to 2010.

Data and Methods

Study Background

Japan has three levels of government: municipal, prefectural, and national. Japanese prefectures and municipalities correspond approximately to states and counties in the United States. Japan had 47 prefectures and 1,750 municipalities at the time of this study.

Data

Data Sources. The data used in this paper come from multiple public data sources. Data for physician and pediatrician totals were obtained from the Survey of Physicians, Dentists, and Pharmacologists (Ministry of Health, Labour and Welfare 2013), which is conducted every 2 years by the Ministry of Health, Labor and Welfare. All licensed physicians must complete this survey and register their working addresses and specialties under the Medical Practitioners Law (Ministry of Health, Labour and Welfare 2010). The estimated registration rate is reported to be between 87 and 90 percent (Shimada and Kondo 2004). The number of under-5-year-old deaths was obtained from the vital registration system (Ministry of Health, Labour and Welfare 2014a; Ministry of Health, Labour and Welfare 2014b). The local population of age group under 5 years old was obtained from the Basic Resident Registers Network (Ministry of Internal Affairs and Communications 2015a). Municipality-level income was obtained from the Statistical Observation by Municipalities, produced by the Ministry of Internal Affairs and Communications (2015b).

Statistical Analysis

The spatial unit of analysis used in this study is Secondary Tier of Medical Care Unit (STMCU), which typically combines several municipalities in Japan. Each prefecture is divided into 5–10 STMCUs on the basis of its transportation network and geographical location. There were 369 STMCUs in Japan at the time of this study, generally considered independent administrative areas from a health service perspective, and less prone to local spillovers than municipalities or counties used in other studies (Miller and Stokes 1978; Grossman and Jacobowitz 1981; Kobayashi and Takaki 1992; Matsumoto et al. 2009, 2010; Odisho et al. 2009; Toyabe 2009; Ono, Hiratsuka, and Murakami 2010). Our outcome of interest is under-5 mortality at the Secondary Tier of Medical Care Unit (STMCU) level in Japan. The primary predictor of interest is the number of pediatricians per 1,000 population under the age of 5 (pediatrician density). Primary care practices are not well established in Japan (Otaki 1998; Takahashi et al. 2010). In general, when the children get sick, guardians immediately consult pediatricians without referral. Given this, pediatricians play the dominant role in pediatric care in Japan, providing primary, secondary, and tertiary care to children.

The earliest publicly available data for the number of under-5-year-old deaths was from 1999 while the most recent data for the number of pediatricians was from 2010 at the time of this study; therefore, the following six time points were used for the analysis: 2000, 2002, 2004, 2006, 2008, and 2010 (The Survey of Physicians, Dentists, and Pharmacologists was not conducted in 1999). Data were obtained at the municipality level and aggregated up to the STMCUs.

Descriptive statistics of all variables are presented as medians with interquartile ranges for the study period. Maps were created to visualize the spatial distribution of under-5 mortality and pediatrician density in 2010. We examined both the change in number of pediatricians between 2000 and 2010 as well as the frequency of change in the number of pediatricians for five 2-year intervals between 2000 and 2010 (i.e., 2002–2000, 2004–2002, 2006–2004, 2008–2006, 2010–2008).

We estimated the following fixed-effects Poisson regression model with the natural log of the under-5 population as an offset to examine the effects of pediatrician density on under-5 mortality. We employed STMCU and year fixed effects to control for time-invariant STMCU-specific factors:

$$Log(U5D_{st}) = \beta_0 + \beta_1 PED + \chi_{st}\gamma + \sum_{s=2}^{366} \lambda_s I_s + \sum_{t=2}^{2010} \alpha_t I_t + \varepsilon_{st}$$

where U5D refers to the number of under-5 deaths in STMCU s at year t; PED refers to pediatrician density in STMCUs at year t; $\boldsymbol{X}$ is a vector of time-varying characteristics at STMCU level, which includes the following four variables: (1) number of physicians other than pediatricians per total population except for under-5-year-old population, and (2) income per total population by year and STMCU; α_t are year fixed effects, which are year-specific effects common to all STMCUs (captured by year dummies); λ_s are STMCU fixed effects, which absorb all STMCU-specific time-invariant effects; and ε is a STMCU and year-specific random error term. The year fixed effects α_t capture general secular and countrywide trends.

The municipalities of Yokohama and Kawasaki in the Kanagawa prefecture, adjacent to the prefecture of Tokyo, contain three and two STMCUs, respectively, because these two municipalities are large cities. However, income statistics are only available at the municipality level. Therefore, as we could not calculate STMCU-level income for these five STMCUs, they were combined into their respective municipalities. For regression models, Yokohama and Kawasaki cities were each regarded as one STMCU, resulting in 366 STMCUs for regression analyses.

Finally, to understand the difference in health outcomes between regions that were well supplied and poorly supplied with regard to pediatricians, we compared under-5 mortality in the top 10 percent of STMCUs with the best pediatrician supply versus the bottom 10 percent of STMCUs in 2-year intervals for the period 2000–2010.

As a sensitivity analysis to assess robustness of results, we used a generalized estimating equations (GEE) model to account for clustering within STMCUs. Because the data were repeatedly measured within STMCUs, residual correlations are possible even when fixed effects are included. These correlations will affect the standard errors of the estimates, which will affect the *p*-values. Therefore, we accounted for within-cluster correlation by using the GEE model.

Placebo Test

One of the threats to causal inference is that changes in pediatric coverage may reflect long-term trends in unobservable determinants of mortality rather than short-term fluctuations in pediatric coverage. If this were true, we should observe statistically significant correlations between both current and lagged levels of pediatrics coverage.

To test the plausibility of our estimate, a placebo test was conducted. The placebo test examines the effect of pediatrician density at year $t + 2$ on under-5 mortality at year t.

$$Log(U5D_{st}) = \beta_0 + \beta_1 PED_{st} + \beta_2 PED_s(t+2) + \chi_{st}\gamma + \sum_{s=2}^{366} \lambda_s I_s + \sum_{t=2002}^{2010} \alpha_t I_t + \varepsilon_{st}$$

If it were true that short-term changes in pediatricians would reflect general STMCU-level trends, we should find (implausible) effects also for changes occurring in subsequent periods.

A two-tailed *p*-value of less than .05 was considered statistically significant. All analyses were performed using *STATA, version 12.* ArcGIS 10.0 (ESRI, Redlands, CA, USA) was used for map illustration.

RESULTS

Table 1 shows the aggregate-level change in dependent and independent variables, as well as the variables to calculate them (i.e., number of under-5-

Table 1: Descriptive Statistics by Year

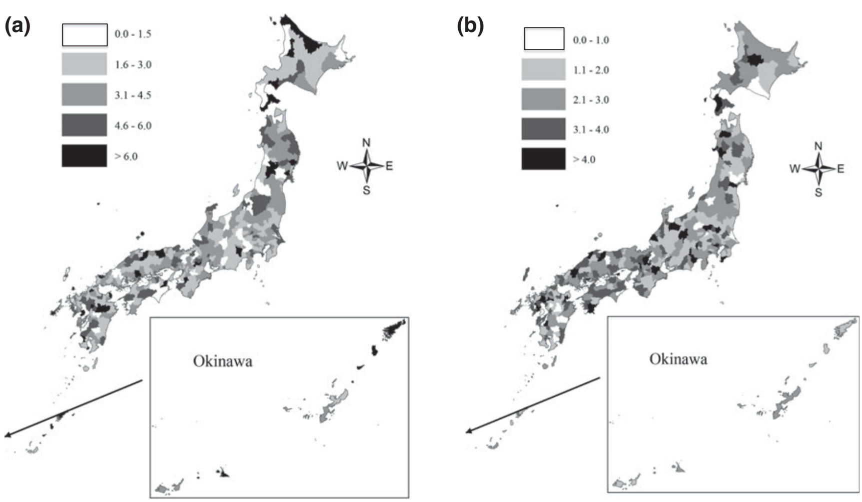
	2000	*2002*	*2004*	*2006*	*2008*	*2010*
Number of under 5 yo death* (A)	5,261	4,736	4,279	3,936	3,742	3,378
Number of birth ('000) (B)	1,190	1,154	1,111	1,093	1,091	1,071
Under 5 yo mortality† (A/B)	4.42	4.11	3.85	3.60	3.43	3.15
Number of pediatrician (C)	14,156	14,481	14,677	14,700	15,236	15,870
Under 5 yo population ('000)‡ (D)	5,901.99	5,865.03	5,753.07	5,569.07	5,441.32	5,383.15
Pediatrician density§ (C/D)	2.40	2.47	2.55	2.64	2.80	2.95
Number of other physicians (E)	229,045	235,093	241,991	248,840	256,661	264,561
Total population ('000)¶ (F)	120,146.89	120,605.54	121,071.10	121,485.95	121,624.86	121,674.71
Other physician density** (E/F)	1.91	1.95	2.00	2.05	2.11	2.17
Income†† ('000,000,000) (G)	188.15	183.68	175.63	186.83	191.31	175.80
Per capita income ('000)†† (G/(D+F))	1.49	1.45	1.38	1.47	1.51	1.38

*Number of under-5-year-old deaths.
†Under-5-year-old mortality.
‡Population under the age of 5.
§Number of pediatricians per 1,000 population under the age of 5.
¶Total population excluding under-5-year-old population.
**Number of total physicians excluding pediatricians per 1,000 total population excluding under-5-year-old population.
††Japanese yen was converted into US$ using the rate that applied in March 2013 of approximately 95 Japanese yen per US$.

year-old deaths, number of births, number of pediatricians, under-5-year-old population, number of other physicians, total population, and income) from 2000 to 2010. Under-5 mortality declined over the period with decreases in both the number of under-5-year-old deaths and number of births. The results of under-5 mortality are consistent with the reports from the World Health Organization, Health Status Statistics (World Health Organization 2010). The number of pediatricians increased while the population under the age of 5 decreased, resulting in the increase in pediatrician density.

Figure 1a and b show spatial distribution of under-5 mortality and pediatrician density in 2010. The highest under-5 mortality rate (20.7) was observed in the Higashi-Kunisaki STMCU in Oita Prefecture, representing four deaths within a small birth cohort of only 193 births in 2010. Highest pediatrician densities were observed for one STMCU (Ku-Chuo STMCU) in the Tokyo Metropolitan Area (304 pediatricians for 29,500 children). Two STMCUs (Kita-Oshima-Hiyama STMCU in Hokkaido Prefecture with 664 children and the South II STMCU in Tokushima Prefecture with 565 children) had zero pediatricians. We examined the distribution of the change in number of pediatricians between 2000 and 2010. More than half of the STMCUs (58.0 percent) had more pediatricians in 2010 than 2000, reflecting the efforts of the Japanese government to increase pediatrician supply. The

Figure 1: (a) Spatial Distribution of Under-5-Year-Mortality in 2010. (b) Spatial Distribution of the Number of Pediatricians Per 1,000 under 5-Year-Old Population in 2010



number of pediatricians in one STMCU in Tokyo (Kita-Tama-Nambu STMCU) increased by 99 between 2000 and 2010, primarily because three children's hospitals in Tokyo were closed to merge into one large children's hospital with 561 beds in this STMCU in 2010. There was a decrease of more than five pediatricians in only 10 STMCUs (2.7 percent of the total STMCUs) between 2000 and 2010. We explored the distribution of the frequency of the 2-year change in number of pediatricians during the study period. Most places had a change in the number of pediatricians every 2 years and there were only two STMCUs (0.54 percent of the total STMCUs) in which the number of pediatricians had no change in 10 years.

Table 2 presents descriptive statistics of dependent and independent variables. Table 3 shows the results from linear regression models to explore the time trend of under-5 mortality and pediatrician density. Under-5 mortality decreased ($p < .001$), while pediatrician density increased ($p < .001$) over time.

Table 4 shows the results from the fixed-effects Poisson regression analysis. Pediatrician density was inversely associated with under-5 mortality. On average, we estimate that a unit increase in pediatrician density was associated with a 7 percent (95 percent CI: 2–12 percent) reduction in the child mortality rate after adjustment for all other variables.

Table 5 shows under-5 mortality in both the top 10 percent of STMCUs in terms of pediatrician supply and the bottom 10 percent. The best-served areas have lower under-5 mortality than the least-served areas during the study period.

The results were consistent and robust across all specifications tested. First, GEE with STMCUs as clusters showed that, on average, one unit increase in pediatrician density was associated with 5 percent (95 percent CI: 3–7 percent) reduction in the child mortality rate at the STMCU level ($p < .01$) after adjustment for all other variables. Second, the results from our placebo test indicated that the effect of the future pediatrician density on the number of deaths was not significant (95 percent CI: −0.90 to 1.02, $p = .15$), suggesting that the observed changes in mortality are attributable to short-term changes in pediatrician coverage rather than general trends in the respective STMCUs. *(Detailed results are available upon request.)*

DISCUSSION

This study was conducted to test a major assumption underpinning health care policy in Japan: the idea that increases in physician supply will positively

Table 2: Descriptive Statistics for Secondary Tier of Medical Care Units (STMCU)

	2000	2002	2004	2006	2008	2010
Median (IQR)						
Under 5 yo mortality*	4.38 [3.43–5.52]	4.03 [3.15–5.33]	3.83 [3.03–5.08]	3.67 [2.7–4.57]	3.3 [2.33–4.22]	3.13 [2.15–4.32]
Pediatrician density†	1.89 [1.51–2.55]	2 [1.53–2.71]	2.09 [1.61–2.84]	2.1 [1.66–2.93]	2.23 [1.74–3.08]	2.35 [1.84–3.23]
Other physician density‡	1.43 [1.2–1.79]	1.47 [1.24–1.84]	1.50 [1.22–1.88]	1.52 [1.28–1.87]	1.54 [1.29–1.88]	1.57 [1.31–1.95]
Per capita income§,¶	11.96 [10.13–13.67]	11.47 [9.63–13.19]	10.77 [9.05–12.44]	11.25 [9.48–13.14]	11.33 [9.38–13.39]	10.52 [8.79–12.13]
Under-5-year-old deaths	8 [3–18]	7 [3–16]	7 [3–15]	6 [3–14]	5 [2–13]	5 [2–12]
Number of pediatricians	15 [7–48]	16 [7–47]	17 [7–48]	16.5 [7–49]	17 [7–51]	17 [7–55]
Under-5-year-old population ('000)	9.04 [4.11–20.55]	8.83 [3.96–20.35]	8.66 [3.81–19.8]	8.26 [3.6–19.53]	7.9 [3.36–19]	7.68 [3.19–18.58]
Number of other physicians**	272.5 [133–771]	279 [135–794]	288.5 [136–808]	284 [131–819]	279.5 [133–839]	281 [128–886]
Total population†† ('000)	189.64 [92.61–402.15]	189.31 [91.9–403.54]	188.51 [91–405.65]	187.01 [89.54–409.32]	184.39 [87.61–408.6]	182.99 [86.21–408.67]
Income¶ ('000,000,000)	2.26 [0.97–5.86]	2.15 [0.91–5.62]	2.00 [0.86–5.29]	2.09 [0.88–5.6]	2.11 [0.87–5.6]	1.91 [0.79–5.17]

*Under-5-year-old mortality (number of under 5 years old death/number of birth*1,000).
†Number of pediatricians per population under the age of 5.
‡The total number of physicians excluding pediatricians per total population excluding population under the age of 5.
§Income per population in thousands.
¶Japanese yen was converted into US$ using the rate that applied in January 2014 of approximately 105 Japanese yen per US$.
**The total number of physicians excluding pediatricians.
††Total population excluding population under the age of 5.
IQR, interquartile range.

Table 3: Trends in Under-5 Mortality and Pediatrician Density

Estimate	*SE*	*95% CIs*		*p-value*
Under-5 mortality (n = 366)				
−0.126	0.013	−0.152	−0.100	<.001
Pediatrician density* (n = 366)				
0.048	0.003	0.042	0.055	<.001

Notes. Numbers represent results from separate linear regression models of STMCU-level mortality and pediatrician density on linear time trends.
*Number of pediatricians per population under the age of 5.

Table 4: Results from a Multivariate Poisson Regression Model (n = 366)

Parameter	*Estimate*	*SE*	*95% CIs*		*p-value*
Pediatrician density*	0.93	0.03	0.88	0.98	.01
Other physician density†	0.53	0.07	0.46	0.6	<.001
Per capita income‡,§	1.04	0.01	1.02	1.06	<.001

Notes. Coefficients represent estimates from a multivariate Poisson regression model with area and year fixed effects. Each observation corresponds to a Secondary Tier of Medical Care Unit in a given year.
*The number of pediatricians per 1,000 population under the age of 5.
†The total number of physicians excluding pediatricians per total population excluding population under the age of 5.
‡Income per total population in thousands.
§Japanese yen was converted into US$ using the rate that applied in October 2014 of approximately 105 Japanese yen per US$.

Table 5: Under-5-Year-Old Mortality of the Top and Bottom Ten Percent of STMCU in Terms of Pediatrician Density

	2000	*2002*	*2004*	*2006*	*2008*	*2010*
Top 10% in pediatrician density* (n = 35)						
Pediatrician density*	4.22	4.31	4.61	4.76	5.01	5.36
Mortality† (A)	4.38	3.99	3.81	3.47	3.14	2.91
Bottom 10% in pediatrician density* (n = 35)						
Pediatrician density*	0.85	0.95	0.98	0.98	1.01	1.03
Mortality† (B)	4.89	4.25	4.06	3.68	3.41	3.26
Ratio in mortality (B/A)	1.12	1.07	1.07	1.06	1.09	1.12
Difference in mortality (B − A)	0.51	0.26	0.25	0.21	0.27	0.35

*Number of pediatricians per population under the age of 5.
†Under-5-year-old mortality (number of under-5-year-old deaths/number of births*1000).

affect population health. The results of this study show consistently positive associations between child health and pediatrician density, and thus support the general notion that increases in pediatrician supply make a positive contribution to the health status of child populations.

Previous studies based on data from developing countries (Flegg 1982; Anand and Barnighausen 2004), or studies including both developing and developed countries (Kim and Moody 1992; Hertz, Hebert, and Landon 1994; Robinson and Wharrad 2000; Farahani, Subramanian, and Canning 2009; Muldoon et al. 2011) have been inconsistent in demonstrating either a beneficial correlation (Flegg 1982; Robinson and Wharrad 2000; Anand and Barnighausen 2004; Farahani, Subramanian, and Canning 2009; Muldoon et al. 2011) or no overall correlation (Kim and Moody 1992; Hertz, Hebert, and Landon 1994) of reduced infant or under-5 mortality with increases in physician supply. Conceptually, the impact of increased pediatrician supply in highly developed countries like Japan is likely substantially different from their impact in developing countries (Eckhert 2002; Ministry of Health, Labor and Welfare 2009; Centers for Disease Control and Prevention 2012a; Centers for Disease Control and Prevention 2012b; Liu et al. 2012; Chopra et al. 2013). While infectious diseases continue to be a major cause of under-5 mortality in developing countries (Liu et al. 2012; Chopra et al. 2013), deaths due to treatable infectious diseases are very few in Japan and the United States (Ministry of Health, Labor and Welfare 2009; Centers for Disease Control and Prevention 2012a). Moreover, the degree of physician shortages in developing countries is substantially greater than in industrialized countries. Eckhert (Eckhert 2002) estimates that the average physician-per-1,000-population ratio in sub-Saharan Africa is 0.1, compared to 2.4 in the United States. Focusing only on the pediatric population, the difference in the physician-per-population would be even greater, given the much larger share of the population in the under-5 age range in most sub-Saharan African countries.

To our knowledge, there are currently only seven child mortality studies focusing on physician supply in industrialized countries, of which three are cross-country studies (Pampel and Pillai 1986; Cochrane, St. Leger, and Moore 1997; Or, Wang, and Jamison 2005) and four are within-country studies (Miller and Stokes 1978; Grossman and Jacobowitz 1981; Vogel and Ackermann 1998; Goodman et al. 2002). Two of the cross-country studies showed an adverse effect of physicians on child mortality (Pampel and Pillai 1986; Cochrane, St. Leger, and Moore 1997), and one showed a beneficial effect (Or, Wang, and Jamison 2005). For example, Cochrane, St. Leger, and Moore (1997) studied 18 developed nations, from which Japan was excluded, and showed an adverse effect of physicians on child mortality. They tested the possibility that this adverse effect was due to the deliberate redistribution of physicians to meet the demand of medical problems by determining whether the increase in the number of doctors between 1960 and 1970 was related to infant mortality in 1960; however, no such relationship was found. Pampel and Pillai (1986) examined 18 developed nations and showed an adverse effect of physicians on infant mortality. They particularly pointed out that Japan has one of the lowest physician-to-population ratios, and yet, it has low rates of infant mortality.

In addition to cross-national studies, within-country studies can also contribute to an understanding of the relationship between human resources in health and population health for the following reasons. First, as Speybroeck et al. (2006) noted, the qualifications, training, classification, and roles of health care workers vary widely from country to country. For example, Japan has neither a primary care physician workforce (as all physicians specialize) nor a physician assistant workforce. Second, as Anand and Barnighausen (2004) stated, "within-country studies are likely to avoid definitional and comparability difficulties arising from nonstandard definitions of health-worker categories across countries." Previous within-country studies based in the developed country context were all drawn from the United States, but results have seemed erratic. Regarding the correlation of physician supply to reducing infant or neonatal mortality, one showed an adverse effect (Miller and Stokes 1978), one showed no association (Grossman and Jacobowitz 1981), a third study showed that the primary care physician supply had beneficial effects, while specialist physician supply had no correlation (Vogel and Ackermann 1998), and the last one showed that neonatal mortality was worse only in regions with the very lowest per capita neonatologist supplies (Goodman et al. 2002).

Geographic regions are likely to have unobserved or unmeasured attributes that may affect child mortality beyond the obvious controls like income and population size included in our empirical model. These unobserved factors could correlate with the explanatory variables and, unless controlled for in the models, can lead to omitted variable bias (Aakvik and Holmas 2006). Using panel models with STMCUs, fixed effects allows us to directly exclude any confounding through factors which do not vary over the relatively short sample period (such as geographic location, average education, age structure), and also to control for general population-level trends through time fixed effects.

In 2007, the Japanese Cabinet decided to raise the number of medical school admissions for the first time in 28 years to increase the number of physicians (Ministry of Education, Culture, Sports, Science and Technology 2011a). Since then, the number of medical school admissions has increased 17 percent, from 7,625 in 2007 to 8,923 in 2011 (Ministry of Education, Culture, Sports, Science and Technology 2011b). The government plans to continue raising the number of admissions until 2019 (Ministry of Education, Culture, Sports, Science and Technology 2011a). The Japanese government's policy to increase the overall number of physicians does not necessarily mean increasing the supply of pediatricians to all regions, and this study only explored the effect of pediatrician supply on child health outcome. An implication of our results is that we have presented clear evidence that investing in human resources in health, in terms of increasing the supply of pediatricians, can be considered part of the strategy to improve the health status of the child population in Japan. We would like to note that increasing the number of physicians does not assure that the overall supply of pediatricians will be enhanced, nor does it help in the supply of pediatricians in areas where the more pediatricians are needed. Sakai, Fink, and Kawachi (2014) showed the number of pediatricians increased where the pediatrician density was already high after 2004, when Japan launched the national matching system, rather than the areas where more pediatricians would be needed. To improve the health status of children, balancing the spatial distribution of pediatricians based on the regional needs should be taken into account with overall increases in the number of physicians.

There are some limitations of this study. First, numerous studies have documented the association between socioeconomic status (SES) indicators and health outcomes (Braveman et al. 2010; Kawachi, Adler, and Dow 2010; Braveman, Egerter, and Williams 2011). Our study used only area-level income as an indicator for SES, because in Japan, education data are collected only every 10 years and occupation data every 5 years. However, education and occupation are strongly correlated with income (Aakvik and Holmas 2006). Therefore, we believe these limitations do not invalidate our results. Second, we did not include the number of nurses due to unavailability of data. However, the role of nurses in Japan is still very limited. Therefore, the physician supply remains the strongest predictor of health outcomes among all human resources in health, and previous studies support it (Anand and Barnighausen 2004). Third, information about work sites, such as clinics or hospitals, was not publicly available at the municipality level. Therefore, this variable could not be considered in the analysis, although the declining number of physicians working in hospitals has been seen as a problem in Japan (Ehara 2007; Toyabe 2009; Ono, Hiratsuka, and Murakami 2010; Tanihara et al. 2011). Fourth, due to the nature of ecological studies, causal inference is not straightforward with grouped data like the one used in this paper. The main advantage of working at the population level is that average population characteristics which may affect mortality of individual children, such as education or occupation, are unlikely to change rapidly over the short periods of time analyzed, which means that all such differences should be absorbed by area and time fixed effects. Having said that, it is clearly possible that other environmental or structural changes, and in particular the establishment of new health facilities, could be correlated with changes in pediatrician density and lead to confounding bias in our analysis. Fifth, the generalizability of the findings in this current study is limited because Japan has very low child mortality (United Nations Children's Funds [UNICEF] 2013) and relies more heavily on pediatricians than other countries for pediatric care. More generally, the qualifications, training, classification, and roles of health care workers vary widely from country to country. Therefore, studies using data from other countries should be conducted to determine whether these findings are generalizable. Sixth, despite the inclusion of spatial and temporal fixed effects, one could argue that local changes in pediatricians may be a reflection of other socioeconomic factors not captured by the aggregate income variable used as control in our empirical model. Our placebo test presented in this paper suggests that the estimated effects do not represent broader trends in pediatrician supply, but rather short-term fluctuation in medical staff available to the population. Even though there is still a possibility that these short-term changes may be correlated with other events at the STMCU level impacting child health, the likelihood of such confounding biases appears rather small in this setting. Last, STMCUs in the same prefecture share medical resources, especially tertiary care, which are controlled by the prefectural health policies/strategies. Given that our main empirical model includes STMCU fixed effects, prefecture effects cannot be directly measured in our model; further research will be needed to better understand the interactions between prefectures and STMCUs.

CONCLUSION

The results of our study suggest that pediatrician supply shows a robust positive association with child health in Japan. These results suggest that Japan's current policy efforts to achieve high and equitable physician coverage across the country are important and likely generating substantial improvements in population health.

More generally, the results presented also suggest that the benefits of improved access to pediatric care are not restricted to high-mortality and low-resource environments but can be detected even in settings where child mortality rates of less than 5 deaths per 1,000 have been achieved.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.